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(Meteorological Office)

AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

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1. Introduction

As part of the investigation of the rainfall mechanism by the Bergeron process, and of the possibility of modifying rainfall over England by injecting artificial freezing nuclei into supercooled clouds, it was decided in 1954 that counts of natural freezing nuclei in the free atmosphere should be made by the Meteorological Research Flight. Measurements on the ground have been described by several authors (Ref. 1, 2, 3) but the only previous airborne measurements in this country were a few by Palmer made in aircraft of the Meteorological Research Flight in 1950 (Ref.4). More extensive work in aircraft by E.J. Smith and K.J. Heffernan of C.S.I.R.O., Australia is described in Ref.5.

After preliminary experiments in the laboratory in which both expansion chambers and cold chambers were tested, it was decided that the latter was more convenient for work in aircraft. Accordingly a cold chamber was constructed very similar to that described by Smith and Heffernan and, after some preliminary flight-tests in the summer of 1955, the techniques outlined in their article were adopted and have since been followed rather closely. This apparatus, although the most convenient at present, has severe limitations and some of them are mentioned below.

Dr. E.G. Bowen of C.S.I.R.O. suggested that flights should be made with this apparatus on as many days as possible during January, 1956, in order to provide data bearing on his hypothesis (Ref.6) that the variations of rainfall are related to the occurrence of meteor showers, and to afford a comparison with a similar series of observations to be made by Smith and his colleagues in Australia. It proved possible to make measurements on 25 days of this month in M.R.F.'s Hastings aircraft and to combine them with other work, e.g., simultaneous measurements of condensation nuclei, temperature, humidity, and cloud structure. In addition several samples were taken during other flights in a beam of silver iodide particles emitted from C.D.E.E., Porton and the results will be presented in another report. The present paper describes the results of the sampling of natural freezing nuclei with particular reference to Dr. Bowen's hypothesis. Some of the measurements of condensation nuclei will be included, but a more complete discussion of these will be given later in a separate paper.

2. Instrumentation

2.1. The cloud chamber consisted of a cylindrical tank 55 cm high and 30 cm diameter, its volume being about 40 litres. It was lagged externally and cooled or heated by circulating methylated spirits in copper pipes brazed round its periphery and in a spiral under its base. The methylated spirits could be pumped electrically either through a spiral immersed in solid carbon dioxide for cooling purposes or through another spiral in a water tank containing a 1 kw

/immersion

immersion heater for heating purposes, before circulating round the cloud chamber. The illumination was provided by a beam of light, at an angle of 45° to the horizontal, from a 250 kw lamp and the inside of the chamber was painted a matt black. Steam was produced by switching on a small immersion heater in a vacuum flask containing distilled water, placed at the bottom of the chamber. The cloud of water droplets or ice crystals produced was viewed through a visor, the illuminated observed volume being about 0.5 litres. Temperature was measured at 10 cm from the bottom and also at 10 cm from the top of the chamber by small 50-gauge platinum-wire resistances connected to M.O. bridges. Essentially the apparatus is similar to that described by Smith and Hefferman but rather smaller. Fig.1 shows its arrangement in the Hastings aircraft. It was located near the tail and air was supplied to it through a copper pipe, 10 cm in diameter, extending from an intake ahead of the propellers. Air passed along this pipe at a speed almost equal to that of the aircraft and consequently the rate of flushing was very high. When a sample had been taken the air supply was shut off and the chamber was sealed, all inlets being airtight and the removable top of the chamber being clamped down on a rubber washer.

2.2. In flight the chamber was flushed for at least a minute before the sample was taken with the chamber at a temperature well above freezing point to avoid any immediate deposition of hoar frost on the walls. The chamber was then cooled continuously at the maximum rate, which was about 5°C/min at 0°C falling off to about 0.5°C/min at -30°C. Details of cooling rate are given in each of the quoted results. If a cumulus cloud is ascending at 20 ft/sec with a lapse rate of 3°F/1000 ft, a particle in it will be cooled at about 2°C/min so that the conditions in the chamber were in this respect somewhat similar to those in a large cumulus cloud. While the temperature was falling, a cloud was maintained in the chamber by switching the boiler on and off at intervals, the cloud being kept at a sufficient density to allow the ice crystals to grow rapidly, but not so thick as to impede visibility. Estimations of crystal concentrations were then made in the range from 0°C to about -30°C. To prepare for a new experiment, the chamber was heated up again by switching the methylated spirits through the heater tank circuit and by flushing out the chamber. As the air passed through the long pipe its temperature increased considerably and there appeared to be no difficulty in taking samples in cloud. No effects of any possible icing at the inlet have yet been noticed. The time between the commencement of successive samples was usually about 30 minutes.

2.3. It is easy to see the crystals in the chamber as they sparkle, in contrast with the dull opaque background of the droplet clouds. The estimation of their concentration however is essentially a subjective one and to ensure as high an internal consistency as possible all the observations quoted throughout this series were taken by one of us (M.P. Garrod).

(a) When there were enough crystals in the chamber a visual estimation of their apparent spacing allowed an estimate of their number per litre to be made. Spacing estimates varied between 20 cm and 0.25 cm.

(b) At very low concentrations the number of crystals seen in the beam during a given period was counted. When the number exceeded about 8 in 30 sec the observer was able to relate this to a spacing: e.g., 8 in 30 sec was equivalent to a spacing of 1 particle per 20 cm. It was then assumed that lower numbers could be linearly related to equivalent spacings from this relationship. The figures obtained in this manner for low concentrations (0.1/litre or less) must be treated with reserve.

There are of course many objections to this procedure. Estimates of spacing, made, as described in para. 2.3.(a), by different observers may differ by as much as a factor three although agreement improves with experience. Any improvement on (b), e.g., by postulating that any crystals seen in the beam must have been produced in the volume of the cloud chamber immediately above the beam requires a knowledge of the fall-velocities of the crystals and of the movements of the air within the chamber.

A purely objective system is difficult to design. For example, any system of photographing the particles requires the use of a microscopic system of small focal depth, which limits the volume that can be photographed. Another system which was tried was to have a disc covered with Formvar rotating under a slot at the bottom of the chamber. Any crystals falling into the slot formed repligas on the disc, and a complete record was obtained for the period when the crystal-concentration was large. However, this method gives no information for very small crystal-concentrations.

3. Limitations of the equipment

3.1. The apparatus is clumsy and more than half an hour is needed to take and examine a sample. By careful design and by the use of large rates of cooling Smith and Heffernan obtained samples in 10 minutes or so. For the sampling of natural nuclei, however, this is a doubtful procedure as there may be a delay before nuclei become active at a given temperature. Even with samples every 10 minutes the scope of the measurements achieved in a given flight is undesirably small. The bulk of this particular apparatus moreover confines its use to large aircraft.

3.2. The subjective nature of the estimations of the concentration of ice crystals has been discussed above. There may also be variations in the rate of production of steam, and hence in the rate of growth of the ice crystals, particularly as the rate of boiling is a function of altitude.

3.3. The visible concentration at a given instant is affected by the following:-

(a) There is a constant depletion of concentration as crystals fall out to the bottom of the chamber. The rate at which they do this depends on their size which is affected by the rate of supply of steam from the boiler.

(b) There is an increase of concentration as more nuclei become activated with time at a given temperature.

Hence there will generally be an uncertainty in evaluating total concentrations due to these two opposing effects, and the best that can be done for natural nuclei is to observe the apparent concentration at given temperatures. Smith and Heffernan have produced conversion factors which take these effects into account when the effective nuclei are silver iodide, by comparing the observed concentration at given times with the total number of crystals falling on to the bottom of the chamber at fixed temperatures. This factor varies linearly from about 30 at -10°C to 2 at -30°C and it is therefore most important at the higher temperatures. Although the few laboratory tests made by M.R.F. showed that a factor of comparable magnitude should be used for natural nuclei, it cannot be applied with any confidence in practice as it may vary from experiment to experiment. The results given below do not include any conversion factor, but this is not thought to affect the validity of comparison between measurements on different days.

3.4. The measurement of the temperature in the chamber presents some difficulties as there is a difference of about 2°C between the top and bottom thermometers at -10°C and 4°C at -30°C. Moreover the temperature is lowered continuously which means that thermometer lags are important. The illuminated area does not include the bottom of the chamber and in the results given below the temperature at the centre of the chamber is quoted. In fact, due to turbulence, ice crystals which are formed in the lower temperature region at the bottom of the chamber may be transported upwards in the beam, and other investigators have given a temperature measured nearer the bottom as that corresponding to a given concentration. The thermometer lag was found by a subsidiary experiment and the correction applied to the indicated readings was obtained from the following expression which gives the reading of a thermometer with lag in an environment whose temperature is changing

$$T_{r+1} - \theta_{r+1} = \frac{\theta_{r+1} - \theta_r}{k \Delta t} \qquad (1)$$

where k is the thermometer lag coefficient (= 0.7 in this case), θ_r, θ_{r+1} are the indicated temperatures at time t, $t+\Delta t$ respectively, and T_{r+1} is the true air temperature at time $t+\Delta t$.

The crystals themselves take some time to grow to a visible size which results in a lower temperature being assigned to their formation. If the time is 30 sec the error is 1 to 2°C.

3.5. As the chamber capacity is about 40 litres and the illuminated area is approximately 0.5 litres the observations are not well based for concentrations less than about 1/litre (Smith and Heffernan consider that the threshold of detection with their 100 litre chamber is 0.1/litre). There is some evidence that smaller concentrations may be significant in rainfall production by the Bergeron process.

Although there is little doubt that the readings are significant at concentrations of 1/litre and above, an observation of a single flashing particle in the beam may be suspect if any dust particle gets into the chamber.

It should also be noted that, in connection with its application to rainfall production, the apparatus does not make any count of small pure ice particles which may be floating in the atmosphere, as they will be melted before the measurement begins. On the other hand there is a danger at the lower temperatures that any hoar frost on the walls of the chamber may fall off and act as a freezing agent.

3.6. Although the limitations of this type of instrument are considerable and the objections to any quantitative results based on its use may be formidable, nevertheless it does give results which are generally reproducible and it determines in a semi-quantitative way the freezing nucleus spectrum for crystal concentrations of 1/litre to about 10^4/litre with indications of the temperature of lower concentrations.

4. Flight details

4.1. During January, 1956 samples were taken on 25 days between 11 a.m. and 3 p.m. at 10,000 ft over Southern England within a 50 mile radius of Farnborough. Temperatures, humidities, and numbers of condensation nuclei were also measured at this level and at different levels on the ascent and descent. These measurements are shown in Fig.2. In connection with other work, raindrop sampling and cloud water content measurement was also carried out whenever possible. On a few flights data on the variation of freezing nucleus counts in the vertical and in the horizontal were obtained. Table 1 lists the detailed observations of ice crystals observed during each experiment.

5. Application of the results to Bowen's hypothesis

5.1. Fig. 3 shows a plot of the temperature at which observed concentrations of 1/litre to 10^4/litre occurred from the 2nd to 30th of January, 1956. The temperatures at which the first crystal was observed in each case are also shown. Included for comparison is a copy of Smith's results giving temperatures at which 1/litre occurred in January, 1955 in Sydney, Australia. Similar curves for Sydney in 1954 and Arizona 1955 are given in Ref.7 in which it is pointed out that in the main they tend to exhibit peaks around the 13th, 23rd and 31st of the month which coincide roughly with the dates of abnormal rainfall in Sydney given by Bowen in Ref.6.

/The

The Meteorological Research Flight results however do not exhibit any well marked peaks and the temperature for the 1/litre concentration is always between -20 and -25°C while the day to day variation at the 10^2, 10^3 and 10^4/litre level is no more than would be expected from random errors of measurement. No conclusions have been drawn from the temperatures at which the first crystal was seen, these being regarded as very doubtful observations. At the 0.1/litre level there was probably a peak on the 28th only.

The mean temperature for the Meteorological Research Flight readings is several °C higher than that of the Australian measurements. It is thought that this can be accounted for by differences in chamber design and reading technique - e.g., rates of cooling and position in the chamber at which the temperature measurement was taken. Considering the spectrum as a whole the day of maximum concentrations was the 4th January although of course it is possible that there may have been a peak during the period from the 5th to the 8th when no flying was possible.

5.2. It appears therefore that this set of measurements give no support to the hypothesis of Bowen, i.e., they do not show any correlation with an expected increase of freezing nuclei concentration on dates falling about 30 days after the occurrence of meteor showers. In a private communication (Ref. 8) Smith informed us that his flight results for 1956 in Sydney also exhibited no well-marked peaks. On the other hand K. Bigg working with a cold box in Carnarvon, Western Australia, on the coast with on-shore winds and virtually no clouds obtained concentrations of 1/litre at about -10°C on 13th, 21st, 23rd and 1st February compared to a general level of about -20°C for the rest of the month.

5.3. It should be noted that whereas the recent Meteorological Research Flight results, and those given in Ref.7, exhibit nucleation temperatures at the 1/litre level which vary from a minimum of -25°C to -30°C to a maximum of -16°C to -20°C, Bigg's results give maxima of -10°C. This point appears to be important as it is fairly well established (e.g., in Ref. 9 and 10) that natural clouds usually glaciate between about -10°C and -15°C. Thus it appears that there is a temperature gap of about 10°C between the temperature at which the clouds glaciate and at which nuclei appear, in concentrations of 1/litre and above, in the cloud chamber experiments. This difference, which has also been noted by previous workers with cloud chambers, makes dubious the support given to Bowen's hypothesis by the results in Ref. 7. Palmer (Ref. 4) has interpreted the difference as "a shortage of freezing nuclei" and has suggested that the discrepancy might be made up by a splintering process from rapidly growing crystals particularly in the dendritic stage at about -15°C.

5.4. It seems likely therefore that the temperature range of most interest for counts of freezing nuclei is between 0 and -20°C. The concentrations here however are frequently as low as $1/m^3$ and can therefore only be investigated with a chamber having a volume of at least $1m^3$. The installation of so large a chamber, together with its heating and cooling system, in an aircraft, would present a serious engineering problem. The present chamber however seems to be adequate for other purposes, e.g., determining concentrations of silver iodide relatively near to a generating source.

5.5. It should be added that although these results do not support Bowen's hypothesis they do not of course disprove it. All that can be said is that the variations of nucleation-temperature, at levels of 1/litre or higher, are small and show no singularities corresponding with those predicted by Bowen's hypothesis. Owing to the limitations of the equipment, one cannot attach very much weight to the observations at lower concentrations, but, such as they are, they likewise fail to support Bowen's hypothesis.

6. Comparison with other cloud chamber results

6.1. It has been pointed out by Findeisen and Schulz, followed later by Palmer and then by Smith and Heffernan, that the earlier results from

expansion chambers indicating a "threshold temperature" for the activation of freezing nuclei were explicable in terms of a spectrum of freezing nuclei. Typical spectra obtained in these flights are shown in Fig.4. The results below the 0.1/litre level are very questionable but there seems to be little doubt that the temperature, at which the main increase of concentration begins, varies from sample to sample. The curve for 4/1/56, for instance, clearly shows considerable increase in activation at about -19°C whereas that of 30/1/56 requires -25°C for the same type of increase. The mean curve for the series is shown in Fig.5 and this is compared with a diagram from Ref.2 from which it appears that the type of curve is rather similar to that observed by other workers.

6.2. The typical shape of the curve in Fig.5 suggests that there may be different types of freezing agents active at temperatures roughly above and below -20°C. The former, in the mean, were not observed above about -8°C and remained at concentrations of less than 0.1/litre between -10°C and -18°C - the range of temperatures in which clouds commonly glaciate. The latter type of nucleus evidently becomes active in greatly increasing numbers as the temperature is lowered. Counts were rarely taken below -30°C in this work.

6.3. In Ref.11 E.K. Bigg has attempted to predict the number of crystals which will occur in a cloud chamber at temperatures below about -25°C when the water content and the rate of cooling are known. He assumes that at these lower temperatures freezing can be regarded as an event whose probability depends on the size of the droplets and the time they are held at given temperatures. His results, which were compared with Smith and Hefferman's mean freezing spectrum from 155 measurements, were considered to justify the application of his laboratory results (obtained by freezing drops suspended in an insoluble liquid) to calculations of the freezing temperature of airborne droplets.

Bigg's results for water contents of 0.3 and 3 gm/m^3 are plotted on Fig.5 using the mean rate of cooling of the Meteorological Research Flight apparatus of 1.3°C/min at -25°C to -30°C. The arithmetic mean of the Smith and Hefferman 155 results is also included in this diagram. Their agreement with the mean spectrum of the Meteorological Research Flight results is not thought to be good, the slope of the curve of the M.R.F. spectrum being considerably greater. This may be partly due to the subjective estimation of the crystal concentration, but may also indicate that between -20° and -30°C freezing nuclei may still be playing a decisive role in the freezing processes.

The day to day variations of concentrations of freezing nuclei were also examined with respect to rate of cooling of the chamber at -20°C and no correlation was found.

7. Sources of freezing nuclei

7.1. Although the variability of the counts was small, it seemed worth while to attempt to find a relationship between freezing nucleus concentrations and other factors such as air mass, wind direction, and vertical stability using Fig.2 and the data in Table 2, which includes information on weather and air mass. In the last column of this table an opinion is given on the likelihood that the nuclei could have been transported upwards from the earth's surface, based on consideration of the lapse rate and the counts of condensation nuclei. Table 3 gives a summary based on these opinions.

/Table 3

Table 3

Number of cases of high, moderate and low concentrations of freezing nuclei at -20°C and -25°C in which transport upwards from the earth's surface was likely

Transported upwards from earth's surface	Freezing nucleus concentration at -20°C			at -25°C		
	High >1/litre	Moderate 0.1-1.0/litre	Low <0.1/litre	High >100/litre	Moderate 10-100/litre	Low <10/litre
likely	1	4	9	2	3	9
unlikely	2	4	4	1	3	6

In general there is no evidence from this table that the higher concentrations were produced by transport of nuclei upwards from the earth's surface but rather the reverse is suggested, i.e., in unstable conditions the counts tended to be low.

7.2. A few flights have been made giving data directly on variation of freezing nuclei in the vertical and the results of these are shown in Fig.6, 7 and 8.

(a) On 19.1.56 counts were made at 2,000 ft and 10,000 ft with an inversion at 4,000 ft ahead of a warm front. The freezing nucleus concentrations were generally higher above the inversion (Fig.6).

(b) On 6.3.56 samples were taken at 1,500 ft and at 5,000 ft with an inversion at 3,000 ft ahead of a warm front. In this case there was very little change with height (Fig.7).

(c) On 30.1.56 counts were made at 10,000 ft, 15,000 ft and 20,000 ft. The lapse rate was unstable throughout and there was considerable cloud and rain ahead of a small wave depression. At concentrations greater than 1/litre the temperature of activation appeared to increase with height. At lower concentrations however the reverse appeared to be the case although of course this is the region where the measurements are doubtful.

7.3. Although the major part of the evidence suggests that most of the condensation nuclei in the free atmosphere up to 10,000 ft at least are produced at the surface and decrease upwards there is not a direct correspondence between the counts of condensation nuclei and vertical stability (Fig.2). Presumably other factors such as the source of the nuclei and the previous trajectory of the air are important. The possibility that condensation nuclei and freezing nuclei arise from the same source was examined with Fig.9 and Fig. 10 which show at the various dates the concentrations of condensation nuclei and of freezing nuclei at -20°C and -25°C respectively. There is no correlation at -20°C but some signs of correspondence between high and low counts of condensation nuclei, and of freezing nuclei at -25°C, can be detected.

The majority of dust and soil substances appear to have activation temperatures lower than -20°C so that any agreement between counts of freezing and condensation nuclei might be expected to be better at the lower temperatures, whereas nuclei active at higher temperatures might, as suggested by Bowen, originate at greater altitudes. Smith and Heffernan found higher activation temperatures for a concentration of 1/litre above inversions than below inversions but otherwise no correlation between the concentration of freezing nuclei and altitude. Palmer on the other hand, detecting concentrations of probably no more than 10/litre, found a "threshold temperature" of -32°C near the surface and -41°C at higher altitudes.

/In

In general therefore the evidence up to date supports the view that the small concentrations of freezing nuclei active at temperatures higher than -20°C are not usually produced at the earth's surface. Those active at -25°C and below may originate there, but in assessing their numbers other factors as well as stability on the day of measurement are probably important. Clearly further measurements are required before any further conclusions can be drawn.

7.4. The question of the variation with wind direction was studied by means of Table 4.

Table 4

Number of cases of high, moderate and low counts of freezing nuclei at -20°C and -25°C in various wind directions

	Freezing nucleus concentration at -20°C			at -25°C		
Wind direction at 10,000 ft	High >1/litre	Moderate 0.1-1.0/litre	Low < 0.1/litre	High >100/litre	Moderate 10-100/litre	Low <10/litre
Northerly			2			2
NW	1	2	2		1	4
W	1	4	7	1	4	7
SW		2	2	1	1	2
S	1			1		

There were no data from the easterly sectors.

No obvious tendency is revealed by this table nor did there appear to be any tendency for large concentrations to be associated with a given air mass.

7.5. Two flights have been made up to date in which variation in the horizontal was examined, and these have shown changes within 100 miles or so as large as the day to day variations at 10,000 ft plotted in Fig.3. This further work also does not support Bowen's hypothesis which presumably requires similar freezing nucleus spectra over considerably greater areas.

The spectra obtained on these two flights are shown in Fig.11 and Fig.12 which both include small synoptic charts.

(a) On 25.1.56 during a flight at 10,000 ft from Farnborough to Aldergrove samples were taken near Stratford-on-Avon and also over the Irish Sea. At concentrations greater than 1/litre the nucleation temperature over the latter place was consistently about 2°C warmer than over the former, for the same concentration. The second sample was taken somewhat nearer to an incoming warm front and in light southerly winds whereas the first was taken in the ridge ahead with light winds and a stable lapse rate. No measurement was made of the lapse rate over the Irish Sea but it was probably stable there also.

(b) On 5.3.56 during a similar flight counts were made over Warwick, Blackpool and Belfast - the last somewhat later in time and at a lower altitude. The W to WNW airstream was stabilising from the west during the period but all counts were made below the inversion. At concentrations of 1/litre and above there appeared to be a significant decrease in counts from south to north.

The two sets of results appear to have little in common except to show that variations in the horizontal exist. It is not thought that the magnitudes of the variations can be accounted for by instrumental uncertainties.

/Finally

Finally an attempt was made to compare counts with the incidence of rainfall which occurred on 10th-12th, 14th, 19th-21st, 23rd, 26th, and 28th-30th. On 23rd and 30th the samples were actually taken in rain and cloud. From an examination of the temperatures for 1/litre concentrations of freezing nuclei on these days it appears that they were days of rather low temperature of activation.

8. Conclusions

8.1. The general results of this series of measurements were as follows:-

(a) No support was provided for Bowen's hypothesis, as freezing nucleus concentrations of 1/litre and above did not vary significantly from day to day and did not exhibit peaks on or near the predicted dates.

(b) Concentrations of 1/litre and above did not usually appear until the temperature had fallen to -20°C or below. This is almost 10°C lower than the temperature at which clouds commonly glaciate and further explanation of this is required.

(c) There was little evidence to suggest that freezing nuclei active at -20°C or above usually originate at the earth's surface.

(d) No correlation of freezing nuclei counts with wind direction, weather or air mass was found although significant changes in concentration were found within horizontal distances of 100 miles or so.

(e) As regards further work it appears that

(i) Apparatus is required capable of counting freezing nuclei in concentrations down to $1/m^3$ in the 0°C to -20°C range.

(ii) A flight programme aimed specifically at finding the origin of freezing nuclei in the free atmosphere is desirable.

(iii) Further efforts should be made to produce a more objective method of making counts.

9. References

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Table 1

Daily counts of freezing nuclei (ice crystals observed)

2. 1.56			3. 1.56		
Time	Temp. °C	Instantaneous number per litre	Time	Temp. °C	Instantaneous number per litre
15.00	-6.7	2×10^{-2}	11.17	-12.7	2×10^{-2}
	-7.0	2×10^{-2}	11.18	-13.5	2×10^{-2}
	-9.8	2×10^{-2}	11.19	-15.3	2×10^{-2}
	-10.7	2×10^{-2}	11.20	-15.8	2×10^{-2}
15.03	-13.2	3×10^{-2}	11.20¼	-16.5	3×10^{-2}
	-15.7	Nil	11.21½	-18.9	-
	-16.5	2×10^{-2}	11.22¼	-20.1	2×10^{-2}
	-16.7	2×10^{-2}	11.23	-20.8	5×10^{-2}
	-17.7	Nil	11.24	-21.4	2×10^{-2}
	-19.0	3×10^{-2}	11.24½	-21.8	2×10^{-2}
	-20.2	3×10^{-2}	11.26	-22.9	5×10^{-2}
15.08	-21.8	6×10^{-2}	11.27¼	-23.3	3×10^{-2}
15.10	-24.0	1×10^{0}	11.28½	-24.6	3×10^{-2}
15.11	-25.5	1×10^{0}	11.29½	-25.4	1×10^{0}
15.15	-28.5	8×10^{3}	11.30¾	-27.0	8×10^{3}
	4. 1.56			9. 1. 56	
11.17½	-7.9	2×10^{-2}	11.34	-4.2	3×10^{-2}
11.18	-9.7	2×10^{-2}		-5.3	2×10^{-2}
11.19½	-12.1	2×10^{-2}	11.36	-9.3	Nil
11.22	-14.4	Nil	11.37½	-12.6	Nil
11.25	-17.8	Nil	11.38	-13.9	Nil
11.27	-19.7	3.7×10	11.42	-16.9	Nil
	-21.0	1.3×10^{2}		-18.5	3×10^{-2}
11.28	-21.8	1×10^{3}		-20.0	2×10^{-2}
11.28½	-25.1	2.4×10^{3}	11.43½	-22.3	2×10^{-2}
	-26.6	8×10^{3}	11.44	-23.6	8×10^{0}
11.30	-27.9	6.4×10^{4}	11.44½	-24.9	3.7×10
				-25.1	1.3×10^{2}
			11.45½	-25.3	1×10^{3}
				-25.7	2.4×10^{3}
			11.46	-26.1	8×10^{3}
			11.47	-27.0	8×10^{3}
			11.48½	-28.1	6.4×10^{4}

Table 1 (continued)

9. 1. 56		
Time	Temp. °C	Instantaneous number per litre
12.08	-4.0	2×10^{-2}
12.09½	-7.8	Nil
12.11	-10.1	2×10^{-2}
12.12	-11.9	Nil
12.13	-13.4	Nil
12.14	-15.3	Nil
12.15	-17.6	Nil
12.16	-18.9	2×10^{-2}
12.16¼	-19.5	2×10^{-2}
12.18	-22.1	8×10^{0}
12.18½	-24.2	1×10^{3}
12.18¾	-24.9	8×10^{3}
12.19¼	-25.8	6.4×10^{4}

10. 1.56		
Time	Temp. °C	Instantaneous number per litre
11.43½	-15.3	2×10^{-2}
11.45	-18.7	Nil
11.45¼	-19.6	2×10^{-2}
11.45¾	-20.6	1×10^{0}
11.46½	-21.9	8×10^{0}
11.47¾	-22.6	1×10^{0}
11.50	-24.6	8×10^{0}
11.50½	-25.2	1.3×10^{2}
11.51	-25.7	1×10^{3}
	-26.0	2.4×10^{3}
11.52	-26.5	8×10^{3}
11.52¾	-27.4	6.4×10^{4}

11. 1. 56		
11.13½	-12.8	2×10^{-2}
11.16	-17.7	2×10^{-2}
11.17	-22.2	1×10^{0}
11.17½	-22.4	1×10^{0}
11.18½	-22.7	8×10^{0}
11.19½	-23.8	8×10^{0}
11.20	-24.5	1.3×10^{2}
11.20½	-25.1	1×10^{3}
11.21½	-25.8	1×10^{3}
11.21¾	-26.1	8×10^{3}
11.22	-26.6	8×10^{3}
11.22½	-27.2	6.4×10^{4}

12. 1. 56		
	-8.4	2×10^{-2}
12.17½	-12.6	Nil
	-12.9	2×10^{-2}
12.19	-14.8	2×10^{-2}
12.21	-18.0	Nil
12.22	-19.7	3×10^{-2}
12.23	-20.1	2×10^{-2}
12.24	-21.4	3×10^{-2}
	-23.1	6×10^{-2}
12.27	-24.8	1.3×10^{-1}
	-26.0	8×10^{0}
	-26.5	1.3×10^{2}
	-26.6	1×10^{3}
12.28	-26.7	2.4×10^{3}
	-26.8	8×10^{3}
12.30	-27.2	6.4×10^{4}

Table 1 (continued)

13. 1.56

Time	Temp. °C	Instantaneous number per litre
11.24	-9.3	2×10^{-2}
11.33	-17.9	2×10^{-2}
11.34	-21.7	1×10^{0}
11.35	-23.2	1×10^{0}
11.36	-23.8	2.9×10^{0}
11.37½	-25.0	8×10^{0}
11.38	-25.5	1.3×10^{2}
11.38¾	-26.4	1×10^{3}
11.39	-26.7	8×10^{3}
11.40	-27.3	6.4×10^{4}

15. 1.56

11.12	-5.6	2×10^{-2}
11.15¼	-10.3	2×10^{-2}
11.16¼	-11.0	2×10^{-2}
11.17½	-12.4	2×10^{-2}
11.20½	-16.9	2×10^{-2}
11.21	-18.3	2×10^{-2}
11.21¾	-18.6	2×10^{-2}
11.22	-19.9	3×10^{-2}
11.22½	-21.3	1×10^{0}
11.23½	-22.5	1×10^{0}
11.24¾	-23.1	8×10^{0}
11.26	-24.5	2.9×10^{0}
11.27½	-25.4	2.9×10^{0}
11.27¾	-25.6	1.3×10^{2}
11.28¼	-26.4	8×10^{3}
11.29	-27.6	8×10^{3}
11.30	-27.7	6.4×10^{4}

14. 1.56

Time	Temp. °C	Instantaneous number per litre
11.21½	-11.7	2×10^{-2}
11.22½	-12.4	2×10^{-2}
11.24½	-15.0	3×10^{-2}
11.25½	-16.2	2×10^{-2}
11.26	-16.7	5×10^{-2}
11.28½	-18.9	5×10^{-2}
11.29	-20.2	1×10^{0}
11.30	-22.2	2×10^{0}
11.31	-23.6	2.9×10^{0}
11.32	-25.2	1×10^{0}
11.32½	-25.7	1×10^{3}
11.33	-26.1	2.4×10^{3}
11.33¼	-26.6	8×10^{3}
11.33¾	-27.2	6.4×10^{4}

16. 1.56

11.25	-6.7	2×10^{-2}
11.26	-8.1	2×10^{-2}
11.26½	-8.2	3×10^{-2}
11.29	-12.4	2×10^{-2}
11.33	-17.3	3×10^{-2}
11.34	-19.7	8×10^{-2}
11.35	-20.6	3×10^{-1}
11.35½	-21.8	8×10^{0}
11.36	-22.9	8×10^{0}
11.38	-24.2	3×10^{-1}
11.38¾	-25.3	8×10^{0}
11.39	-26.0	3.7×10
11.39¼	-26.1	1×10^{3}
11.39½	-26.7	2.4×10^{3}
11.39¾	-27.3	8×10^{3}
11.40	-27.4	6.4×10^{4}

Table 1 (continued)

17. 1.56

Time	Temp. °C	Instantaneous number per litre
11.23	-5.6	2×10^{-2}
11.25	-10.1	2×10^{-2}
11.26½	-12.1	2×10^{-2}
11.28	-13.4	2×10^{-2}
11.31	-17.4	2×10^{-2}
11.32	-19.1	3×10^{-1}
11.33¾	-19.9	3×10^{-1}
11.35	-21.0	2×10^{-2}
11.36¾	-21.9	8×10^{-2}
11.38	-22.8	9×10^{-2}
11.40	-23.3	5×10^{-2}
11.41½	-24.8	1×10^{0}
11.42	-25.5	8×10^{0}
11.42¼	-26.1	1×10^{3}
11.42½	-26.3	2.4×10^{3}
11.42¾	-27.1	8×10^{3}
11.43¼	-28.1	6.4×10^{4}

19. 1.56

13.30	-4.2	2×10^{-2}
13.33½	-12.4	2×10^{-2}
13.35	-14.0	5×10^{-2}
13.36	-14.5	3×10^{-2}
13.37	-14.6	3×10^{-2}
13.39	-16.6	3×10^{-2}
13.40	-18.9	8×10^{-2}
13.41	-20.6	3×10^{-1}
13.42	-21.7	2.9×10^{0}
13.42¾	-23.1	8×10^{0}
13.43½	-24.2	1.6×10
13.43¾	-24.8	3.7×10
13.44¼	-25.6	1×10^{3}
13.44½	-25.9	8×10^{3}
13.44¾	-26.1	6.4×10^{4}

18. 1.56

Time	Temp. °C	Instantaneous number per litre
11.11½	-7.4	2×10^{-2}
11.15	-10.8	2×10^{-2}
11.20	-17.6	2×10^{-2}
11.20¼	-19.0	6×10^{-2}
11.21	-20.0	1×10^{0}
11.22	-21.8	2×10^{0}
11.23	-23.0	1×10^{0}
11.24	-24.6	1×10^{0}
11.24½	-25.0	8×10^{0}
11.25	-25.4	1.6×10
11.25¼	-25.6	1.3×10^{2}
11.25½	-25.9	1×10^{3}
11.26	-26.2	8×10^{3}
11.26¾	-26.8	6.4×10^{4}

20. 1.56

13.12	-4.0	2×10^{-2}
13.13	-5.0	2×10^{-2}
13.16	-7.4	3×10^{-2}
13.20	-9.6	3×10^{-2}
13.21½	-15.3	3×10^{-2}
13.23½	-17.7	3×10^{-2}
13.24½	-19.3	5×10^{-2}
13.25	-20.0	5×10^{-2}
13.27	-20.7	5×10^{-2}
13.29	-21.1	3×10^{-2}
13.29½	-21.9	1×10^{0}
13.31	-22.8	2.9×10^{0}
13.33	-23.8	3×10^{-1}
13.36½	-25.5	1×10^{0}
13.37	-26.2	8×10^{3}
13.38	-27.6	6.4×10^{4}

Table 1 (continued)

Time	Temp. °C	Instantaneous number per litre
21. 1.56		
11.36	-16.9	3×10^{-2}
11.38	-17.6	2×10^{-2}
11.40	-18.7	3×10^{-2}
11.41	-19.8	3×10^{-2}
11.42	-20.7	5×10^{-2}
11.43½	-20.7	5×10^{-2}
11.45	-21.7	3×10^{-1}
11.47	-22.3	9×10^{-2}
11.48	-22.9	1×10^{0}
11.49	-23.4	1×10^{0}
11.52	-24.6	1.3×10^{-1}
11.52½	-25.6	1×10^{0}
11.52¾	-26.1	8×10^{0}
11.53	-26.3	1.3×10^{2}
11.53½	-26.6	1×10^{3}
11.54	-27.4	2.4×10^{3}
11.54¼	-27.6	8×10^{3}
11.55	-29.0	6.4×10^{4}
23. 1.56		
10.48½	-16.1	2×10^{-2}
10.54½	-22.0	5×10^{-2}
10.55	-22.6	3×10^{-1}
10.55½	-23.1	1×10^{0}
10.56½	-23.7	3×10^{-1}
10.57½	-24.6	1×10^{0}
10.58¾	-25.0	8×10^{0}
11.02	-25.9	1.3×10^{2}
11.04	-26.6	1×10^{3}
11.04½	-27.4	8×10^{3}
11.05	-27.9	6.4×10^{4}

Time	Temp. °C	Instantaneous number per litre
22. 1.56		
11.35½	-22.3	2×10^{-2}
11.36	-22.6	3×10^{-2}
11.36¼	-23.2	1×10^{0}
11.36½	-23.7	8×10^{0}
11.37	-24.3	1.6x10
11.37½	-24.9	3.7x10
11.38½	-25.8	1.3×10^{2}
11.39	-26.6	1×10^{3}
11.39½	-26.7	2.4×10^{3}
11.39¾	-27.0	8×10^{3}
11.41½	-28.6	6.4×10^{4}
24. 1.56		
11.15½	-6.6	3×10^{-2}
11.16½	-7.4	2×10^{-2}
11.18	-7.9	2×10^{-2}
11.21	-10.3	2×10^{-2}
11.22½	-13.3	3×10^{-2}
11.30½	-18.3	3×10^{-2}
11.34	-20.0	5×10^{-2}
11.35½	-21.1	5×10^{-2}
11.36½	-21.8	1.3×10^{-1}
11.38	-22.9	5×10^{-2}
11.39	-23.3	3×10^{-1}
11.40	-23.8	2×10^{0}
11.41½	-25.3	8×10^{0}
11.43	-26.1	1.6x10
11.44½	-26.7	1.3×10^{2}
11.46½	-27.6	1×10^{3}
11.50	-28.1	2.4×10^{3}
11.50½	-28.6	8×10^{3}
11.51½	-29.1	6.4×10^{4}

Table 1 (continued)

25. 1.56

Time	Temp. °C	Instantaneous number per litre
11.15	-6.0	3×10^{-2}
11.15½	-6.1	2×10^{-2}
11.16½	-6.7	2×10^{-2}
11.20½	-10.3	3×10^{-2}
11.22	-14.0	3×10^{-2}
11.23	-15.1	2×10^{-2}
11.29	-20.1	2×10^{-2}
11.31½	-21.3	3×10^{-2}
11.33	-23.5	1.3×10^{-1}
11.33½	-24.0	3×10^{-1}
11.33¾	-24.3	1×10^{0}
11.34	-24.6	2×10^{0}
11.35	-25.2	8×10^{0}
11.36	-25.6	1.6×10
11.36½	-25.8	3.7×10
11.37	-26.1	1.3×10^{2}
11.38	-26.6	3×10^{2}
11.38½	-26.9	1×10^{3}
11.39½	-27.2	8×10^{3}
11.40	-27.8	6.4×10^{4}

27. 1.56

12.58	-10.2	3×10^{-2}
12.59	-11.5	6×10^{-2}
13.00	-12.7	3×10^{-2}
13.03	-15.6	5×10^{-2}
13.05½	-17.3	3×10^{-2}
13.06½	-18.7	3×10^{-2}
13.07½	-19.9	1.3×10^{-1}

26. 1.56

Time	Temp. °C	Instantaneous number per litre
11.43	-8.4	2×10^{-2}
11.44½	-10.9	3×10^{-2}
11.45½	-12.4	3×10^{-2}
11.46	-14.2	5×10^{-2}
11.47½	-15.3	6×10^{-2}
11.49	-17.5	6×10^{-2}
11.50½	-19.9	1×10^{0}
11.51½	-21.5	2.9×10^{0}
11.53	-23.1	4.6×10^{0}
11.53½	-23.9	8×10^{0}
11.54	-25.0	1.3×10^{2}
11.54¼	-25.2	1×10^{3}
11.54½	-25.8	8×10^{3}
11.55	-26.6	6.4×10^{4}

27. 1.56 (continued)

13.09	-20.8	3×10^{-1}
13.09¾	-21.3	1.3×10^{-1}
13.10	-21.7	1×10^{0}
13.11½	-23.3	1×10^{0}
13.12	-24.4	2.9×10^{0}
13.12½	-24.7	1.6×10
13.13	-25.5	3.7×10
13.13½	-26.1	1×10^{3}
13.14	-27.2	8×10^{3}
13.15	-27.8	6.4×10^{4}

Table 1 (continued)

28. 1.56

Time	Temp. °C	Instantaneous number per litre
11.37	-7.6	1.1×10^{-1}
11.37½	-8.0	5×10^{-2}
11.38¼	-8.8	8×10^{-2}
11.38¾	-10.0	1.1×10^{-1}
11.40¾	-11.5	5×10^{-2}
11.41½	-13.5	8×10^{-2}
11.43	-16.0	2×10^{-2}
11.44½	-17.6	3×10^{-2}
11.45½	-19.1	3×10^{-2}
11.46½	-20.1	9×10^{-2}
11.48	-21.3	3×10^{-2}
11.49	-22.9	1.3×10^{-1}
11.50	-24.0	3×10^{-1}
11.50¼	-24.7	8×10^{0}
11.51	-25.4	1.6×10
11.51¼	-25.6	1.3×10^{2}
11.52½	-25.8	1×10^{3}
11.53½	-26.4	2.4×10^{3}
11.53¾	-26.6	8×10^{3}
11.54½	-27.2	6.4×10^{4}

29. 1.56

Time	Temp. °C	Instantaneous number per litre
11.30½	-9.4	2×10^{-2}
11.33½	-11.9	3×10^{-2}
11.34½	-13.3	2×10^{-2}
11.37	-17.1	2×10^{-2}
11.38	-18.1	2×10^{-2}
11.39	-20.2	1.1×10^{-1}
11.40	-21.5	9×10^{-2}
11.40½	-22.2	3×10^{-1}
11.42	-23.1	1×10^{0}
11.43½	-24.4	3×10^{-1}
11.44	-25.3	1×10^{0}
11.44¼	-25.5	8×10^{0}
11.44½	-26.1	8×10^{3}
11.45	-26.6	6.4×10^{4}

30. 1.56

Time	Temp. °C	Instantaneous number per litre
11.03½	-6.7	5×10^{-2}
11.05	-10.1	5×10^{-2}
11.06½	-11.2	3×10^{-2}
11.09½	-13.1	5×10^{-2}
11.11	-16.2	3×10^{-2}
11.12½	-17.5	2×10^{-2}
11.13	-18.5	2×10^{-2}
11.14	-19.2	2×10^{-2}
11.15½	-20.3	2×10^{-2}
11.15¾	-20.5	1.3×10^{-1}
11.17	-22.6	1.3×10^{-1}
11.18	-23.4	1.3×10^{-1}
11.19½	-23.6	3×10^{-2}
11.20½	-24.6	1.3×10^{-1}
11.20¾	-24.9	1×10^{0}
11.21	-25.4	8×10^{0}
11.21½	-25.6	1×10^{3}
11.22	-26.2	8×10^{3}
11.22½	-26.7	6.4×10^{4}

Table 2

Comparison of freezing nuclei counts with other observations

Date Wind at 10,000 ft Air mass	Vertical ascent	Cloud and weather	Condensation nuclei	Freezing nuclei per litre		Remarks on freezing nuclei
				at -20°C	at -25°C	
2. 1.56 Northerly Cold Polar	Inversion at 4,000 ft. Subsidence, dry above	Small Cu. only	Decrease above inversion. Number average	3×10^{-2} Low	1×10^{0} Low	Little chance of supply from ground
3. 1.56 NE'ly ahead of weak warm front	Inversion at 4,000 ft probable subsidence	8/8 Sc. topped by inversion	Decrease above inversion. Number below average	1.7×10^{-2} Low	1.3×10^{-1} Low	Number very low
4. 1.56 Light S'ly Anticyclonic	Inversion near surface	No cloud. Haze top 2,000 ft. Also haze above 7,500 ft	Very low throughout	4.6×10 High	2.4×10^{3} High	Freezing nuclei counts high. No correlation with condensation nuclei and little transport from surface. Origin could have been extra-terrestrial
No observations 5. 1.56 - 8. 1.56 inclusive						
9. 1.56 W'ly ahead of ridge of High	Inversion at 4,000 ft	8/8 Sc. topped by inversion. Some light snow	Considerable decrease to low values above inversion. Readings variable	1.7×10^{-2} Low	7×10 Moderate	Doubtful whether supply could have come from below
10. 1.56 SW'ly Post cold front	Unstable	Cu. and Cb. to 20,000 ft. Some rain	Low counts	9×10^{-2} Moderate	4×10 Moderate	Supply could have been from below, although condensation nuclei counts low

Table 2 (continued)

Date Wind at 10,000 ft Air mass	Vertical ascent	Cloud and weather	Condensation nuclei	Freezing nuclei per litre		Remarks on freezing nuclei
				at -20°C	at -25°C	
11.1.56 WSW'ly	Rather unstable	Cb. locally. Also thin Sc. layers. Showers	Low counts	1.7×10^{-2} Low	8×10^{2} High	Supply could have been from below, although condensation nuclei counts low
12.1.56 W'ly Post-wave	Rather unstable	Sc. layer 5,000 to 10,000 ft. Rain	Below average	1.7×10^{-2} Low	2.5×10^{-1} Low	Supply could have been from below, although condensation nuclei counts low
13.1.56 W'ly Ridge of high pressure	Fairly stable	No cloud. Haze top 4,000 ft. Very dry	Below average	1.7×10^{-2} Low	8×10^{0} Low	Supply could have been from below, although condensation nuclei counts low
14.1.56 SW'ly	Unstable	Layered cloud to 10,000 ft and above	Below average decreasing with height	5×10^{-1} Moderate	1.2×10^{0} Low	Doubtful if supply came from below - some decrease with height of condensation nuclei
15.1.56 W'ly airstream	Fairly stable	4/8 Sc. at 2,500 ft. Rather dry above	Moderate and variable. Constant with height	3.3×10^{-2} Low	2.9×10^{0} Low	Could have come from below
16.1.56 WNW airstream	Unstable to 7,000 ft. Small inversion	1/8 Sc. at 5,000 ft	Rather small-decreasing with height	1×10^{-1} Moderate	1.5×10^{0} Low	Doubtful if supply could have come from below
17.1.56 W'ly airstream	Inversion at 4,000 ft	St. near surface otherwise dry	Rather large decreasing with height	3×10^{1} Moderate	1.5×10^{0} Low	Possible transport from below in spite of inversion
18.1.56 NW'ly Post cold front	Small inversion at 4,000 ft	1/8 Cu. dry above	Below average decreasing with height	1×10^{0} High	8×10^{0} Low	Doubtful if transport possible from below

Table 2 (continued)

Date Wind at 10,000 ft Air mass	Vertical ascent	Cloud and weather	Condensation nuclei	Freezing nuclei per litre		Remarks on freezing nuclei
				at -20°C	at -25°C	
19.1.56 WNW'ly Pre warm front	Stable. Inversion at 4,000 ft	Cu. 3,000 to 3,500 ft. Ac.As. 7,500 to 8,500 ft and also above 9,700 ft	Above average	1.5×10^{-1} Moderate	6x10 Moderate	Transport from below unlikely
20.1.56 W'ly Warm sector	Unstable to 5,000 ft. Inversion above	8/8 Sc. 3,000 to 5,500 ft. Very dry above. Slight rain	Below average. Decrease above inversion	5×10^{-2} Low	7×10^{-1} Low	Transport from below unlikely
21.1.56 W'ly Pre warm front	Rather unstable	No low cloud. 8/8 Ac.As. Rain later	Below average	3.3×10^{-2} Low	2.6×10^{-1} Low	Transport from below possible
22.1.56 W'ly Post cold front	Fairly stable	8/8 Ac.As. above 7,000 ft	Rather high	Nil	4x10 Moderate	Some transport from below possible
23.1.56 NW'ly Cold frontal	Unstable	Cloud layers 1,800 to 3,500 ft, 4,500 to 8,000 ft. More above. Rain	Very high	Nil	8×10^{0} Low	Transport could definitely have come from below
24.1.56 NW'ly	Unstable	No cloud	High	5×10^{-2} Low	6.3×10^{0} Low	Transport could have come from below
25.1.56 NW'ly Ridge of high pressure	Stable inversion at 6,000 ft	No cloud	High	1.7×10^{-2} Low	5.1×10^{0} Low	Transport from below doubtful in spite of high condensation nuclei counts

Table 2 (continued)

Date Wind at 10,000 ft Air mass	Vertical ascent	Cloud and weather	Condensation nuclei	Freezing nuclei per litre		Remarks on freezing nuclei
				at -20°C	at -25°C	
26.1.56 W'ly Warm sector	Rather unstable	8/8 St. 1,000 to 7,500 ft. Slight rain	No data	$1x10^{0}$ High	$1.2x10^{2}$ High	Transport could probably have come from below
27.1.56 W'ly Weak occlusion	Rather unstable	Local Cu., tops 7,000 ft	Very high	$1.3x10^{-1}$ Moderate	$2.2x10$ Moderate	Transport could have been from below
28.1.56 W'ly Warm front	Fairly stable	Layers 500 to 1,500 ft, 2,500 to 4,000 ft, 7,500 to 8,000 ft. Slight rain	Generally low	$1x10^{-1}$ Moderate	$1.1x10$ Moderate	Transport from below unlikely
29.1.56 W'ly Cold frontal	Unstable	8/8 Nb. St. 800 to 10,000 ft. Rain	No data	$1x10^{-1}$ Moderate	$6.3x10^{-1}$ Low	Transport from below unlikely
30.1.56 Light SW'ly Secondary depression	Unstable	Layers 800 to 1,200 ft, 3,200 to 5,400 ft, 7,200 to above 20,000 ft. Rain	High. Decrease with height	$1.7x10^{-2}$ Low	$1.4x10^{0}$ Low	Transport from below possible

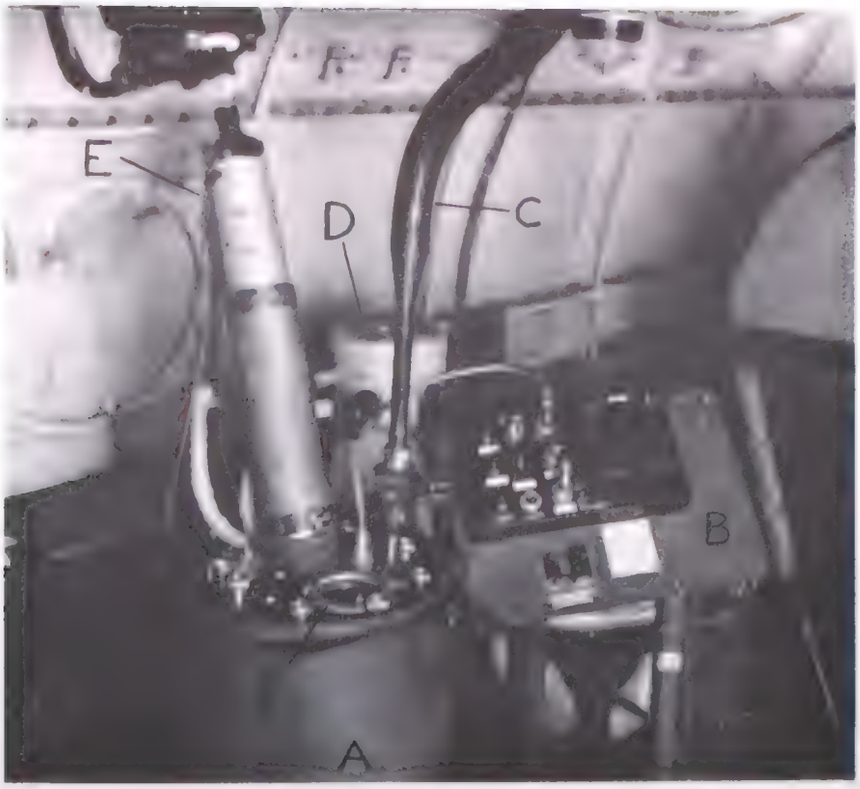


FIG. 1

EXTERNAL ARRANGEMENT OF THE CLOUD CHAMBER

A. 40 LITRE CHAMBER

B. CONTROL PANEL (SOLID CO_2 CONTAINER BENEATH)

C. AIR INTAKE PIPE

D. ELECTRIC PUMP - COOLING CIRCUIT

E. INTERNAL ILLUMINATION UNIT

F. VIEWING PANEL

NOTE: HEATING UNIT NOT ILLUSTRATED

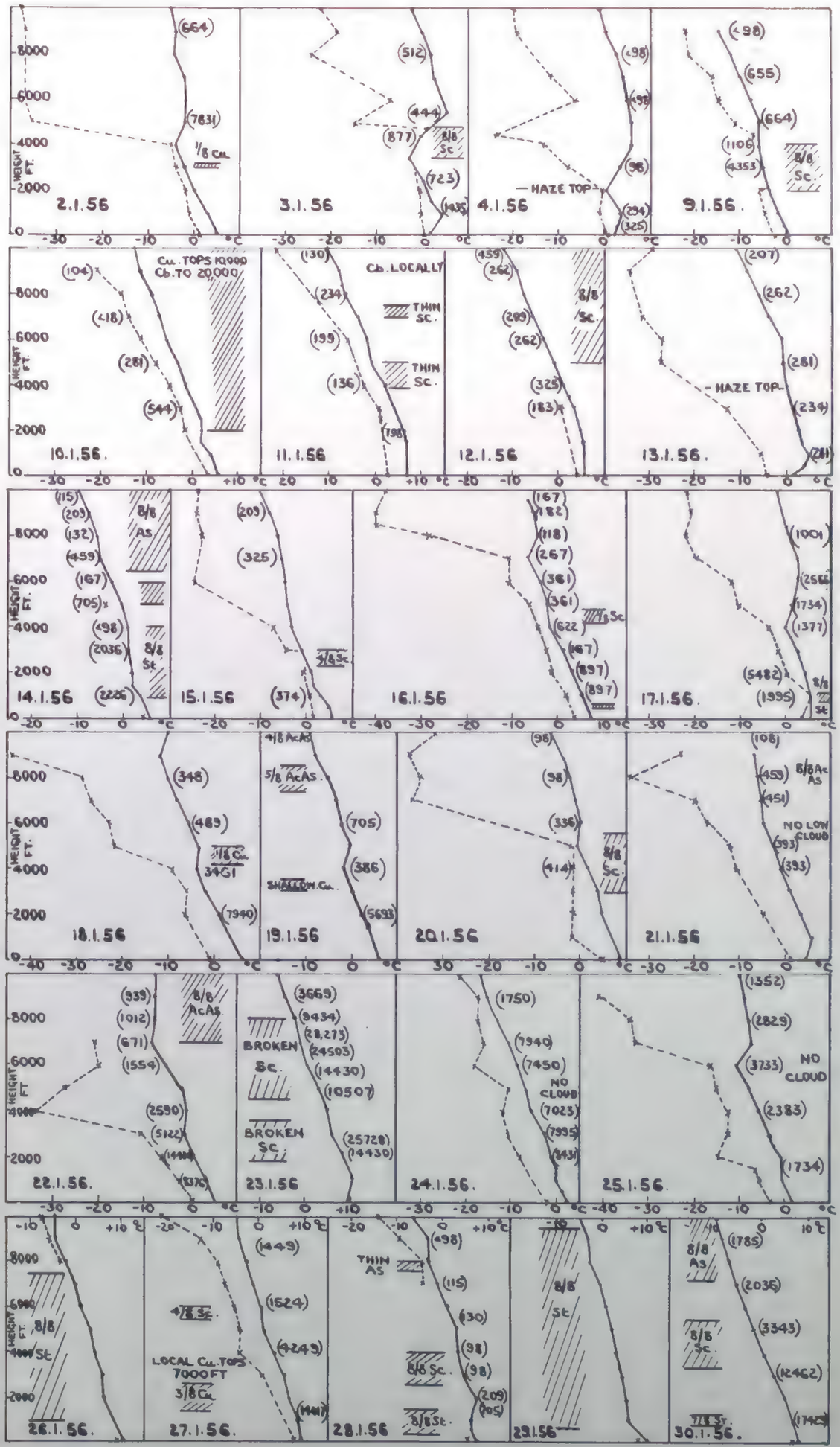


FIG. 2 DAILY AIRCRAFT ASCENTS

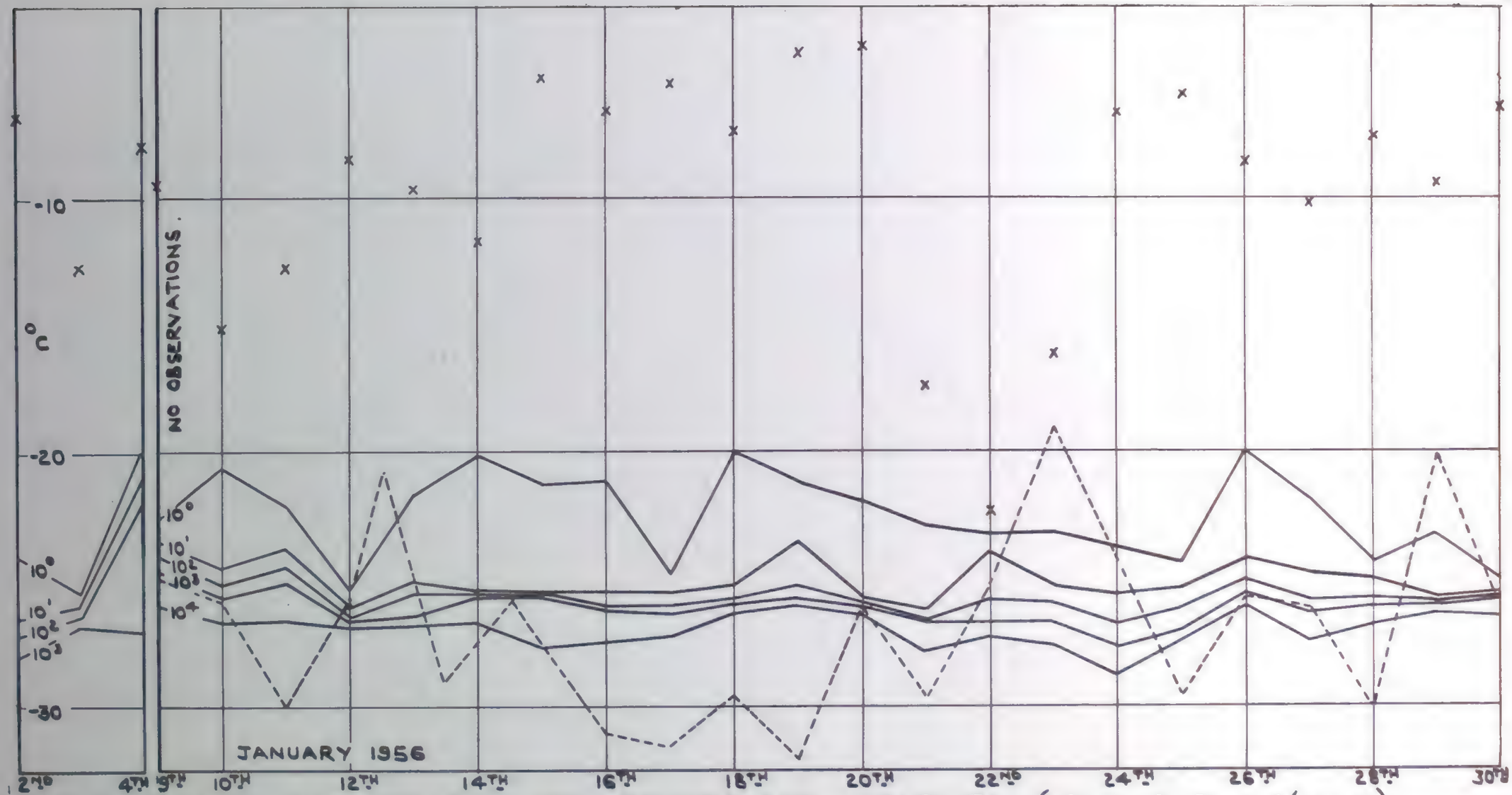


FIG. 3 DAILY VARIATION OF FREEZING NUCLEI. (10^0, 10^1, 10^2, 10^3 & 10^4/LITRE)

ONE SAMPLE EVERY DAY AT 10,000 FT. OVER SOUTHERN ENGLAND. (———)

SIMILAR MEASUREMENTS IN AUSTRALIA. JAN. 1955. OF 1/LITRE ONLY. (- - - -)

TEMPERATURE AT WHICH ICE CRYSTALS WERE FIRST OBSERVED. (X)

MRP998

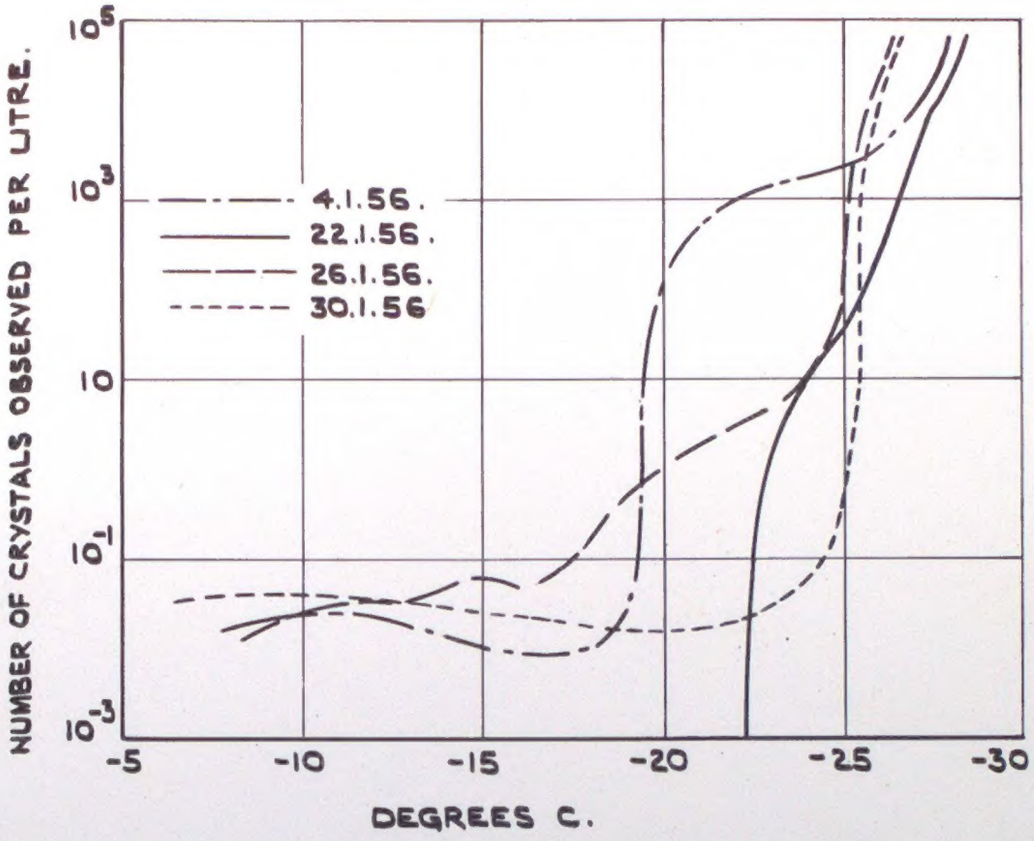


FIG.4 TYPICAL SPECTRA OF FREEZING NUCLEI AT 10,000 FEET.

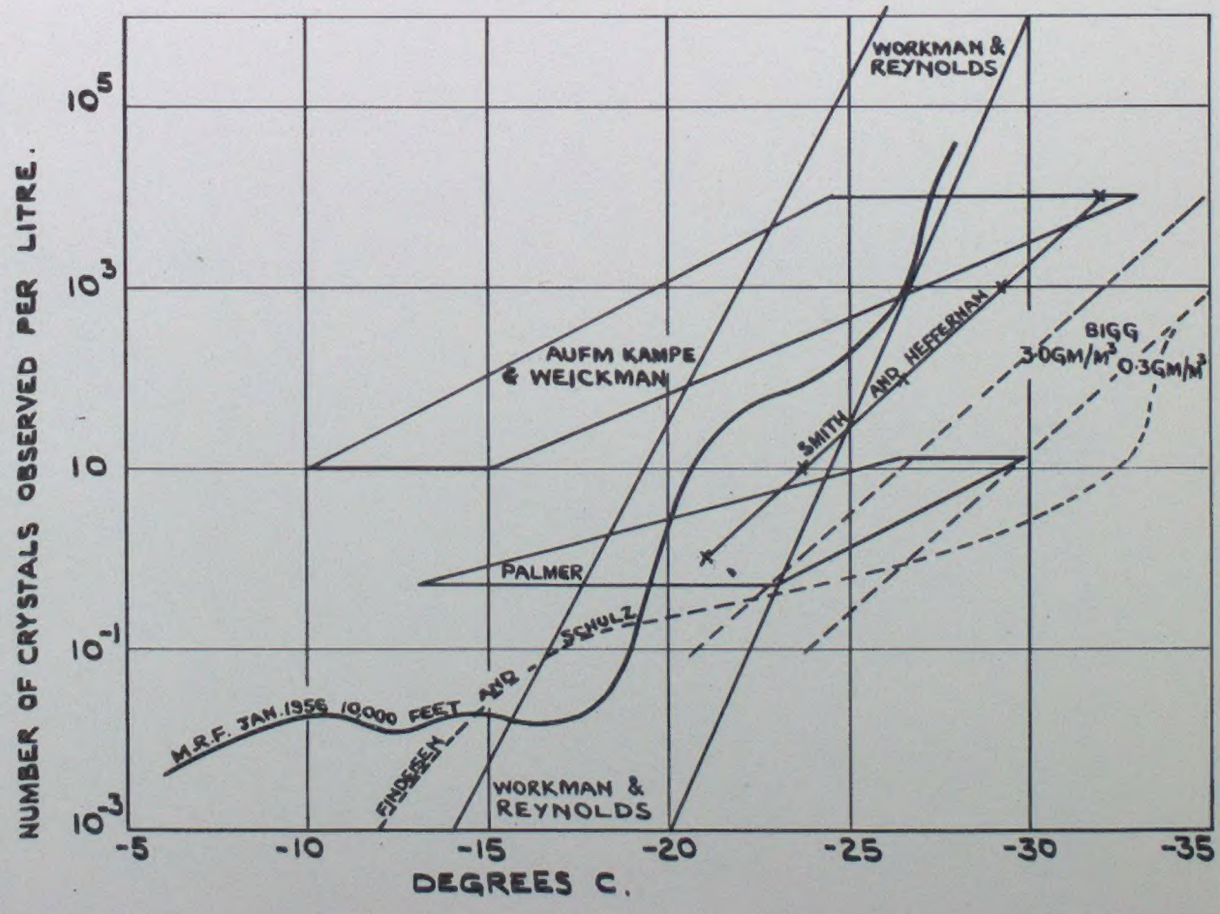


FIG.5 COMPARISON WITH OTHER RESULTS.

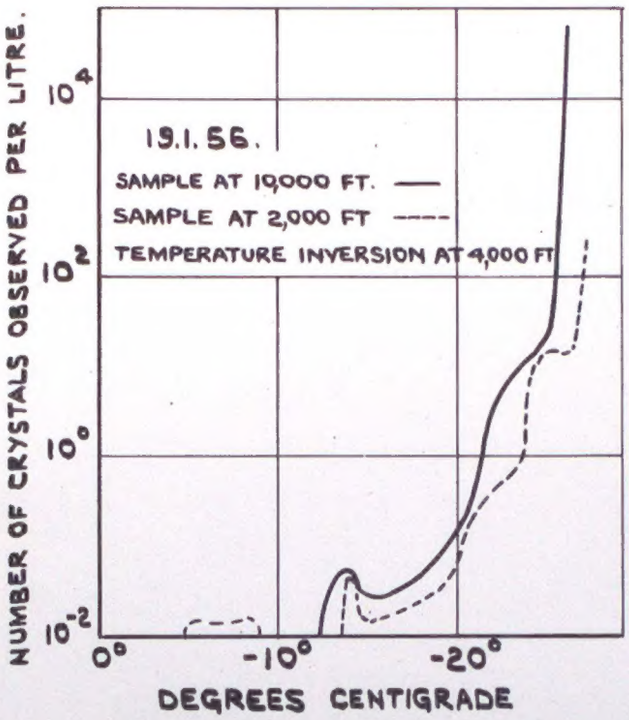


FIG. 6

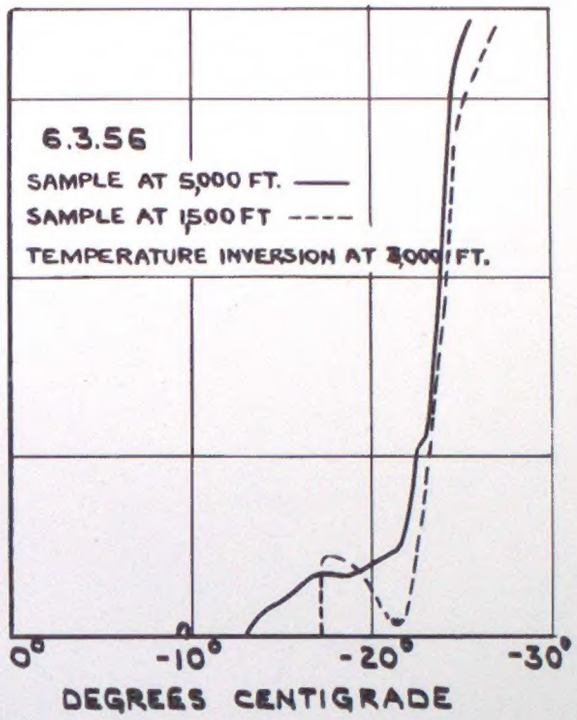


FIG. 7

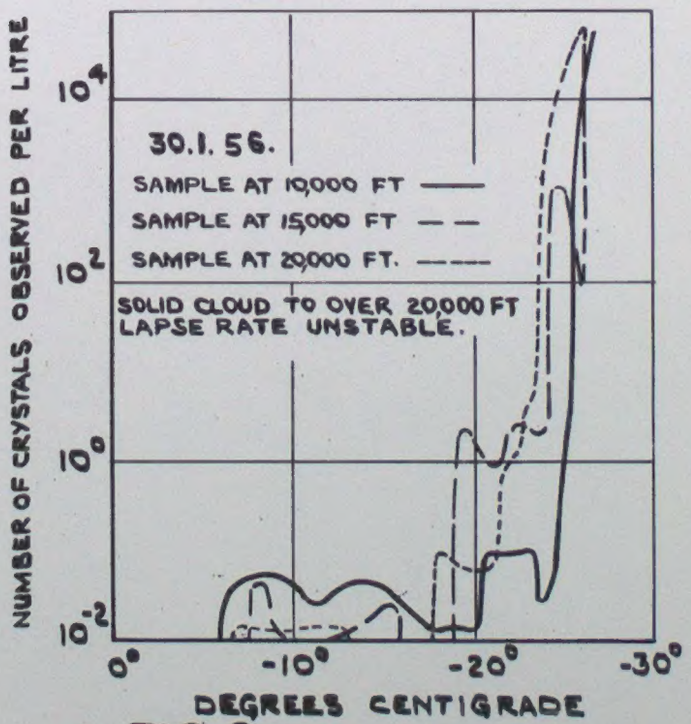


FIG. 8

FIG. 6,7 & 8 VARIATION OF FREEZING NUCLEI WITH HEIGHT.

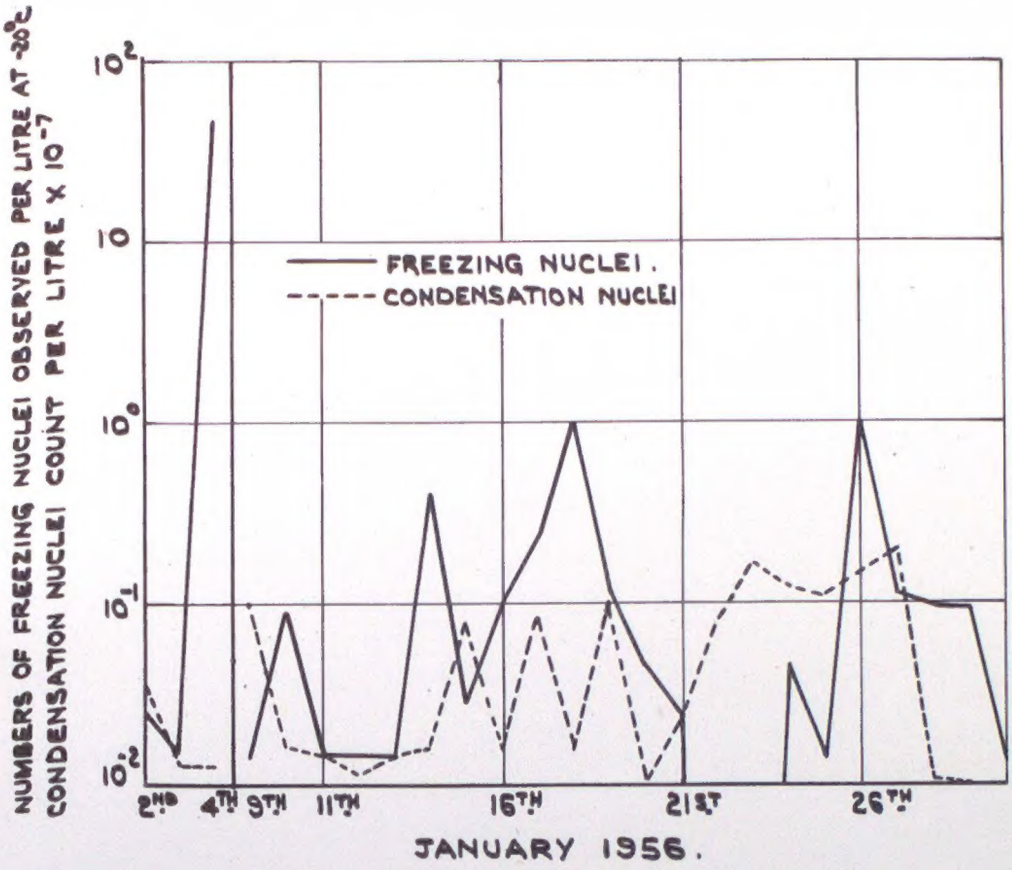


FIG. 9 COMPARISON OF FREEZING NUCLEI ACTIVE AT - 20°C. WITH CONDENSATION NUCLEI. 10,000FT.

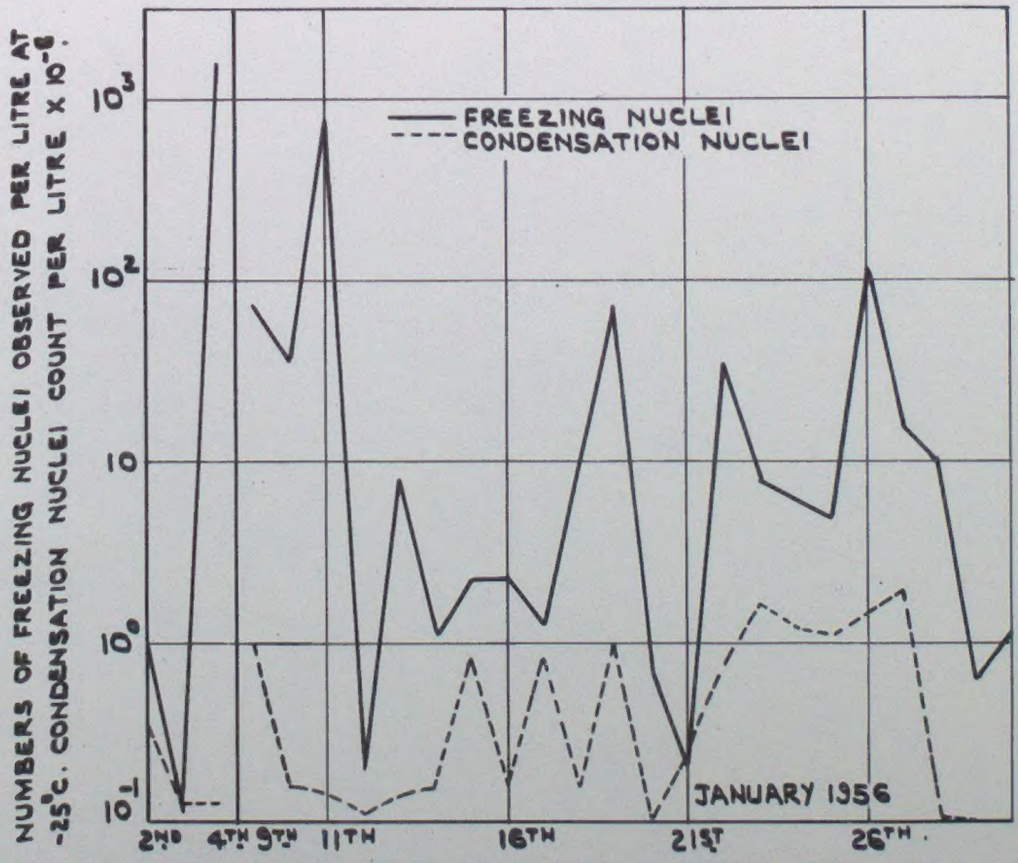


FIG. 10 COMPARISON OF FREEZING NUCLEI ACTIVE AT - 25° C. WITH CONDENSATION NUCLEI. 10,000 FT.

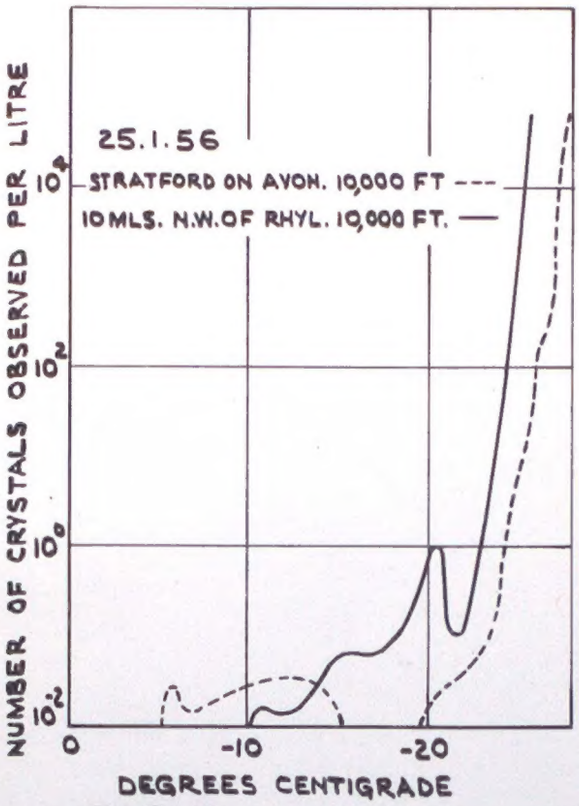
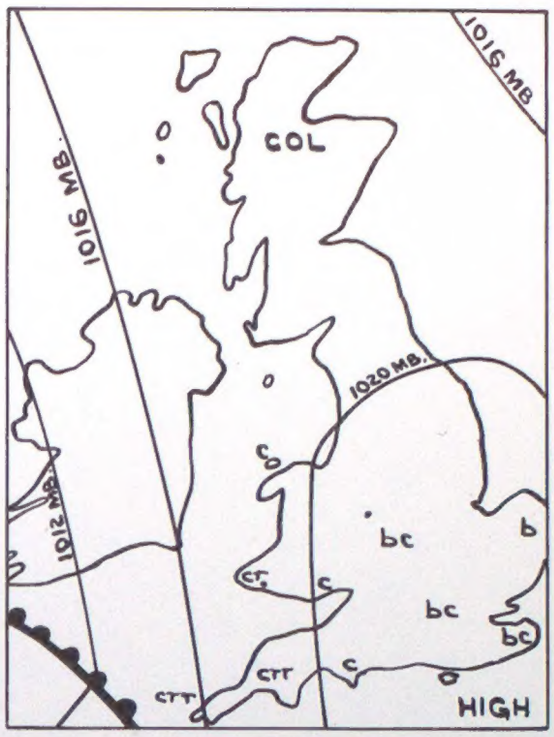


FIG. 11



SYNOPTIC CHART, 1200 G.M.T. 25.1.56.

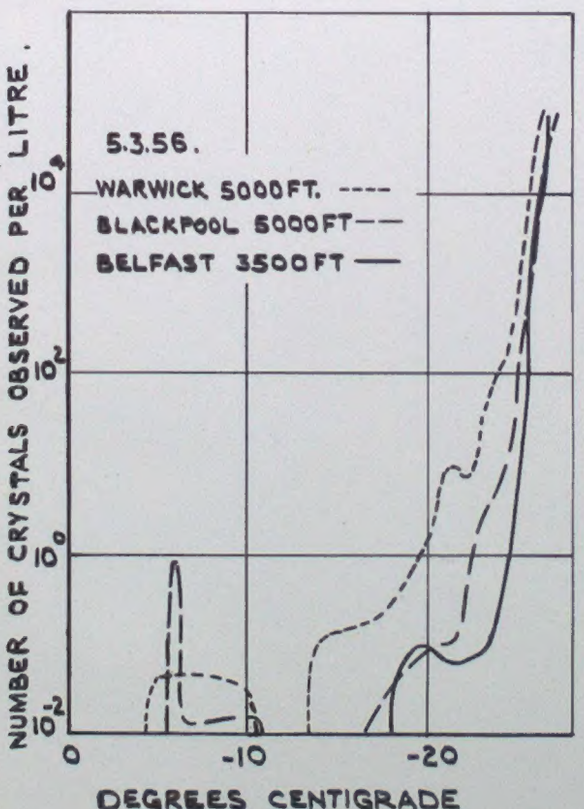
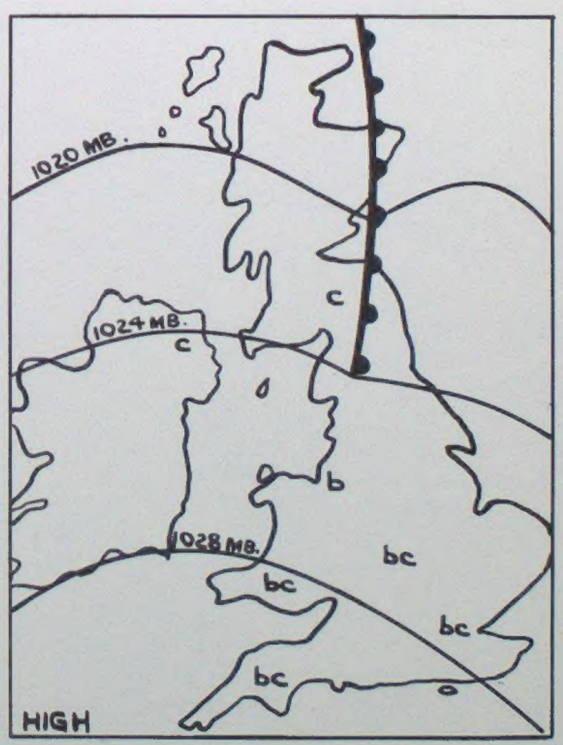


FIG. 12



SYNOPTIC CHART. 1200 G.M.T. 5.3.56.

VARIATION OF FREEZING NUCLEI IN THE HORIZONTAL.